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THERMAL PERFORMANCE ANALYSIS OF SABUNKARAN RESIDENTIAL BUILDING TYPOLOGY

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Abstract: Creating typology is a comparative method to investigate the physical or other characteristics of the built environment. It can be a useful instrument to facilitate the thermal performance assessment of existing buildings. Heat material's resistance and construction techniques play a significant role in energy performance of buildings. It is influenced by many factors, such as ambient weather conditions, building structure, and heating, ventilation and air-conditioning systems.

The study was focused on analyzing five types of residential buildings at the center of the Sulaimani city (north of Iraq) to assess the energy performance of the building types and comparing results with dynamic analyses, using IDA ICE 4.7.1 software. The results revealed that the thermal performance of the buildings is mostly influenced by the variations in the construction techniques and materials.

Keywords: Building typology, Thermal performance, Building simulation

1. Introduction

Typology is the comparative study of physical or other characteristics of the built environment. It is also a way of thinking that does not refer to the age but to the place. As Frank and Schneekloth says 'types and ways of typing are used to produce and reproduce the material world and to give meaning to our place in it' [1]. The term building typology describes a classification of buildings according to some specific characteristic, which are related to the building thermal or energy performance [2]. The thermal performance of the building refers to the process of modeling the energy transfer between a building and its surroundings [3]. A modeling of the building energy performance and a sensitivity analysis of the different aspects affecting the building energy behavior are necessary to optimize the building's energy design or perform an energy audit [4].

The residential building sector is the first largest energy consumer. According to the annual report of the Kurdistan Ministry of Electricity and Energy (KMEE), 70% of the total energy consumption is generated by the residential building sector. To improve the environmental performance of building it is essential to involve all parameters which control its energy efficiency [5]. The most effective methods to develop highly efficient, sustainable building systems is the research programs based energy simulation and monitoring of the building management systems, to be able to predict and minimize the total energy needs of the building [6].

2. Energy consumption in Kurdistan

In recent years, with the rapid development of urbanization, faster population growth, people's incomes and living standards, building energy consumption have increased dramatically especially in the residential buildings. Internationally, energy consumption of the residential sector accounts for 16-50% of that consumed by all sectors, and it averages approximately 30% worldwide [7]. While the residential building sector accounts 70% of the total energy consumption in Kurdistan as it is shown in *Fig. 1*. Therefore, the energy consumption management is a very significant problem not only to take the losses resulting from increasing consumption patterns, but also to improve the performance of building energy systems [8].

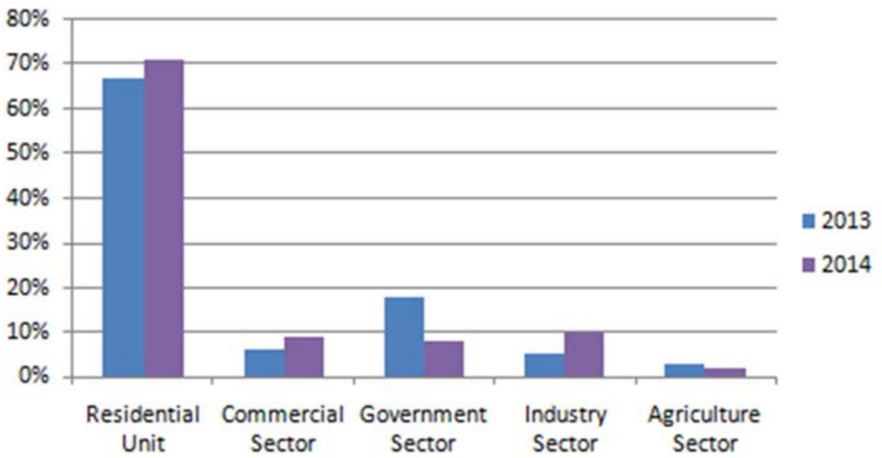

Fig. 1. Energy consumption by end use of Kurdistan, on the basis of [9]

2.1. Energy consumption in Sulaimani

According to the annual report of the KMEE, in 2014 the electricity consumption for acclimatization and lighting residential buildings in Sulaimani was 71% of the total national generated electricity as it is shown in *Fig. 2*, [9].

Residential buildings in Sulaimani are constructed in a single-family detached house, single-family terraced house and apartment blocks form as it is shown in *Fig. 3*.

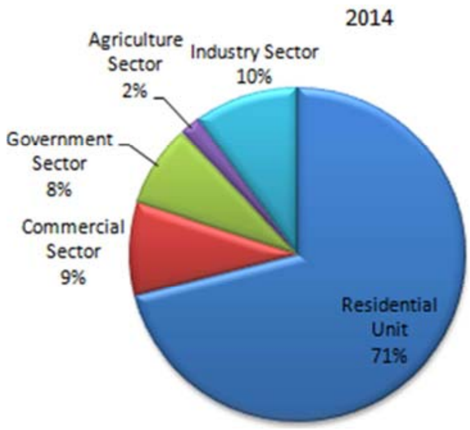

Fig. 2. Energy consumption by end use of Sulaimani, on the basis of [9]

Fig. 3. Examples of Residential Buildings in Sulaimani

2.2. Residential household energy consumption

It is important to present an anatomy of energy end-uses in the residential buildings, to assess the energy performance analysis, while this information is not available in Kurdistan. Therefore, this study evaluated a middle-income urban residential community in Kurdistan.

Fig. 4 shows the greatest user of energy in residential buildings is for cooling (electricity). The second largest use is for heating (electricity) followed by domestic hot water (electricity), plug loads, and other uses. 58% of the consumed energy stands for indoor air conditioning (heating and cooling).

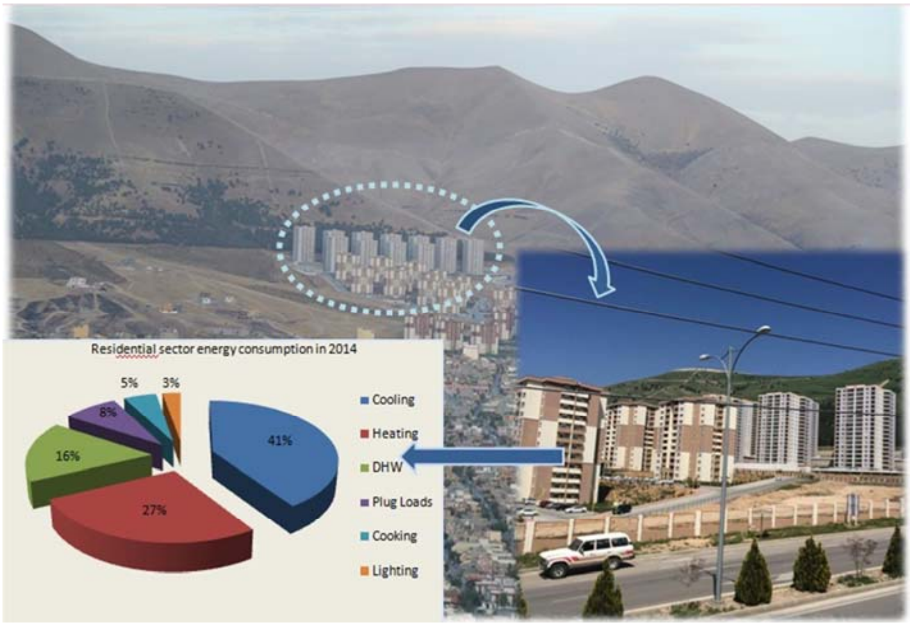

Fig. 4. Energy Consumption per Household in Goizha city, Sulaimani

3. Residential building types in Sabunkaran

In average, 98% of the world's building stock consists of existing buildings [10]. In addition, the study of the existing building types of a certain period reflects the life of this community and gives its urban image. This image is determined by civilization factors in terms of cultural, geographical, social, technical, political and economic indicators. All these indicators contribute to giving qualities and properties and relations for housing patterns within a particular community [11]. From this point, the study classifies the residential building types in Sabunkaran, which located in the center of Sulaimani city that took place through a field survey that was done by the researcher on the existing house's buildings within the study area. Five types were identified as it is shown in *Fig. 5* and is analyzed based on their morphological and compositional properties.

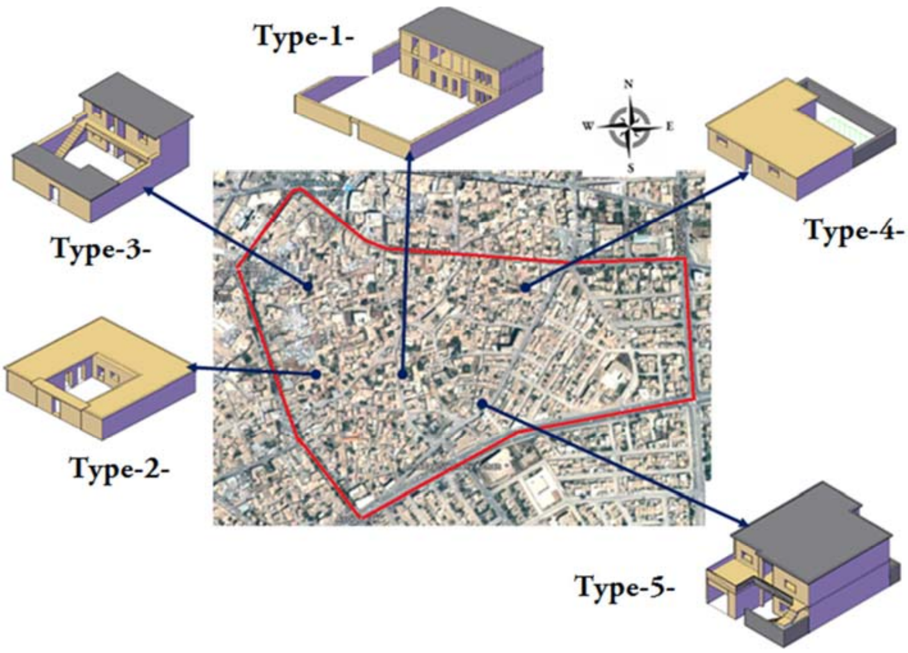

Fig. 5. Residential building types in Sabunkaran

3.1. Morphological properties of residential buildings

Morphological properties include analyzing building materials, wall thickness, building orientation, window and opening size, entrance and access to the house, and land plot size.

Mostly, Type 1 is the traditional residential buildings in Sabunkaran. It consists of two floors; it has characterized by an open front big patio. According to the built materials, clay brick is used as a wall built with a thickness ranged between (40-80) cm, mud or clay is used for the interior and external wall finishing. While the house roofing was made of boles of trees, which diameters not exceed than 15 cm - it was used as the form of cross-beams, which covered by a layer of mat, then placed a layer of compressed soil with a thickness 20 cm on it [12]. Furthermore, building oriented toward the inside, and the size of the land plot ranged from a medium to large, as it is shown in *Fig. 6*.

The Type 2 is semi-traditional buildings, mostly resembling the type one in terms of walls and roof construction materials, the size of the opening and the window. It differs from the first type in the size of the land plot that ranges from medium to small, and it is characterized by the central courtyard, as it is shown in *Fig. 7.*

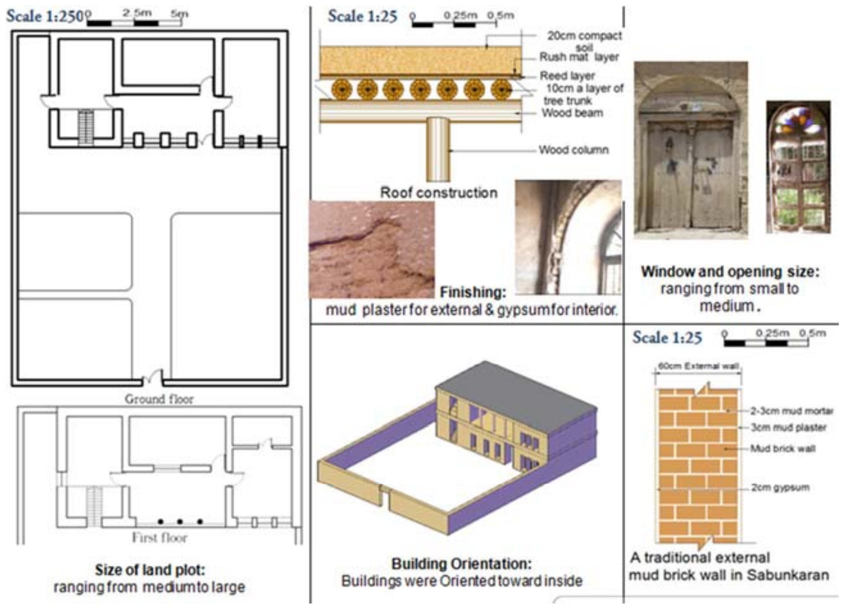

Fig. 6. The Morphology properties of Type-1

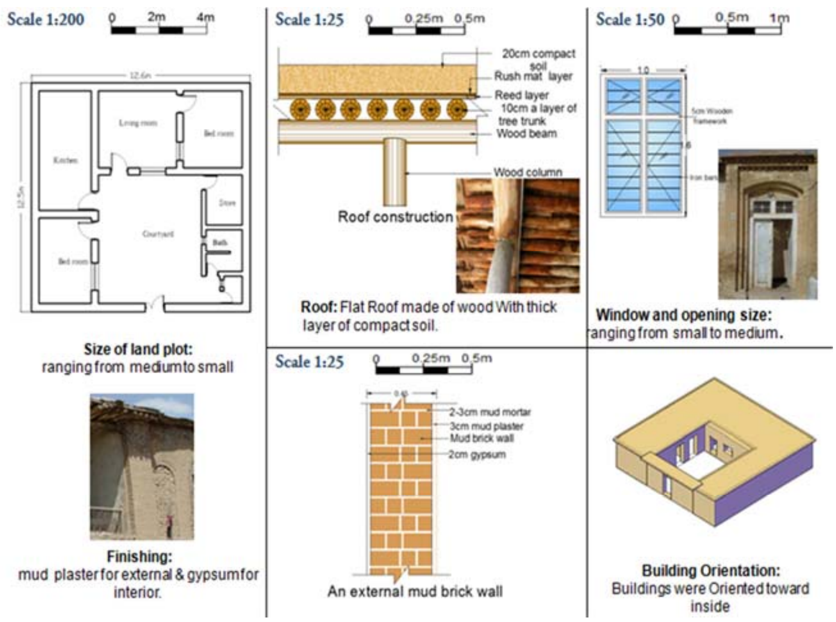

Fig. 7. The Morphology properties of Type-2

While Type 3 usually consists of two stores, the main characteristic is the use of local stone beside the mud-brick and sometimes was used together, especially at the entrance of the building. In addition, the size of the openings was increased, in comparison with the previous types. However, the spaces oriented toward inside around the central courtyard, as it is shown in *Fig. 8*.

The main feature that distinguishes Type 4 with other previous types is the use of reinforced concrete for roofing the buildings. In addition, stone and bricks were used together without external finishing, mostly the building oriented towards inside through the back yard and toward outside through small windows across the facade at the height 1.5 m as it is shown in *Fig. 9*.

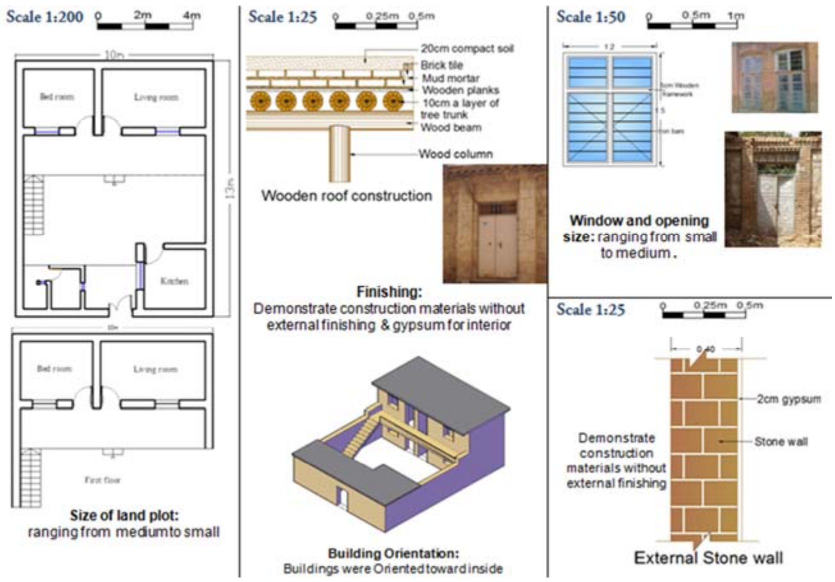

Fig. 8. The Morphology properties of Type-3

Type 5 is tending to modern houses as it is shown in *Fig. 10* is characterized by a front small yard and consists of two floors, In addition; it has two entrances; the small one leads to the house's space while the big entrance leads to the garage. The hollow cement blocks were used for constructing external and internal walls of a thickness 20 cm and roofing the house of reinforced concrete with a thickness 15 cm [12].

3.2. Compositional properties of residential buildings

Compositional properties of a space organization are characterized by the open space dominance over the building mass, as in the first type. In addition, there is a balance between mass and space, as in Type 2, Type 3. However, in the Type 4 and Type 5, the building mass is dominant on the open space.

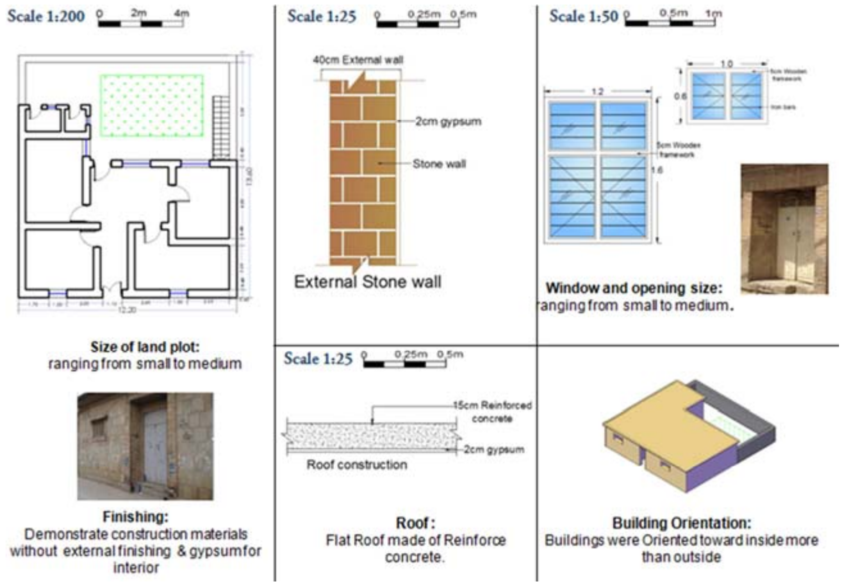

Fig. 9. The morphology properties of Type -4

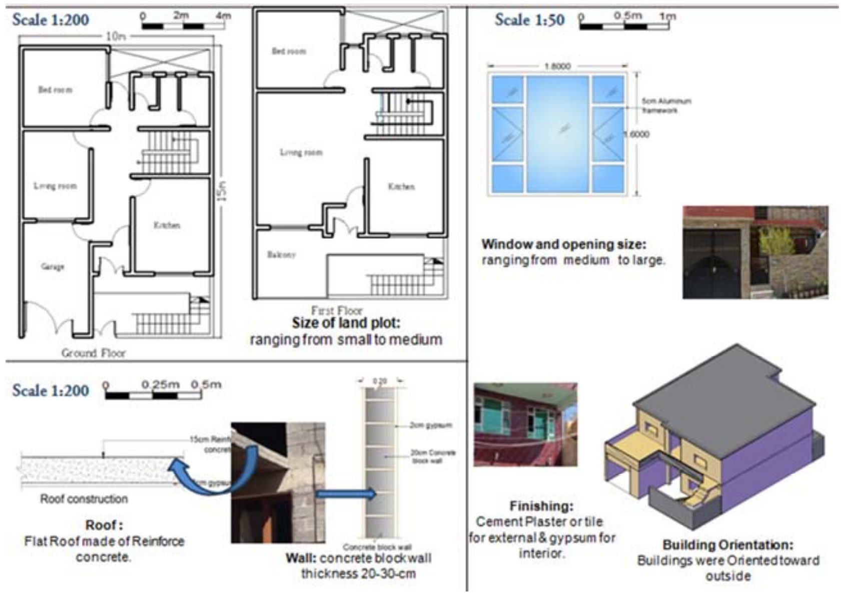

Fig. 10. The Morphology properties of Type -5

According to space organization, there was overlapping between spaces and functions, as in Type 1, Type 2. While in Type 3 began to separate service function with the other functions, it is an indicator to the beginning of the transformation of the space organization. In addition, in the Type 4, Type 5 giving more privacy for space functions, and separate spaces based on their function.

Through in *Fig. 6 - Fig. 10* it can be observed that the morphological and compositional characteristics are changed progressively. This is the nature of the change in the characteristics of residential constructions in many communities despite their different cultures.

4. Methodology

For the purpose of assessing the energy performance of the residential building types, there is a need for accurate calculation and modeling tools. The methodology uses the Indoor Climate and IDA ICE 4.7.1 software, with integrated measurement data, made on the Sulaimani Meteorology Authority (SMA) at the height of 10 m from ground level [13].

The objects being analyzed and compared are five types of residential buildings in Sabunkaran (Sulaimani city center), by assuming the same orientation and weather data in a whole year period in 2014, where the building materials and construction techniques are variable.

5. Energy performance analysis of the typologies

The analyzing of five types of residential building's energy performance by the dynamic building physics model using IDA ICE 4.7.1 software is done as it is shown in *Fig. 11*.

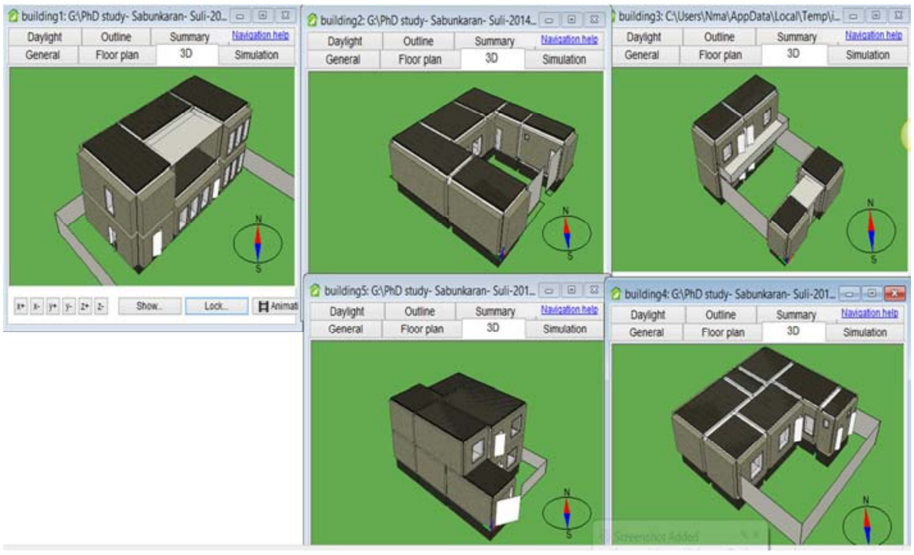

Fig. 11. IDA ICE computational models for residential building types

After simulation the models and comparative results from IDA ICE by comparing the total energy for each type as it is in shown in *Table I*, it can be concluded:

- The best residential building type in terms of energy-efficiency performance is type two;
- The type one performed as the second best model;
- There is a similarity between type three and four in terms of energy efficiency;
- Type five is the largest energy consumer, and it was considered the worst type.

Table I

Total supplied energy report of the models from IDA ICE

	building1		building2		building3		building4		building5	
	kWh	kWh/m2	kWh	kWh/m2	kWh	kWh/m2	kWh	kWh/m2	kWh	kWh/m2
Lighting, facility	1839	11.6	920	11.5	1051	15.5	1051	13.4	2234	11.2
Electric cooling	5949	37.6	2074	25.9	3729	55.0	4525	57.8	7968	39.8
HVAC aux	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Electric heating	8421	53.2	6516	81.3	6283	92.6	6597	84.2	8883	44.4
Total, Facility electric	16209	102.3	9510	118.6	11063	163.1	12173	155.4	19085	95.4
Fuel heating	19508	123.2	14179	176.8	26568	391.6	28163	359.6	43182	215.8
Total, Facility fuel*	19508	123.2	14179	176.8	26568	391.6	28163	359.6	43182	215.8
Total	35717	225.5	23689	295.4	37631	554.7	40336	515.1	62267	311.2

By analyzing the supplied energy results as shown in *Table I*, it is evident that Type 1 of the residential building requires only 225.5 kWh/m^2, while Type 2 requires 295.4 kWh/m^2. Furthermore, Type 5, which is the largest energy consumer, and the worst type in terms of its energy performance, it required 311.2 kWh/m^2. Both Type 3 and Type 4 required 554.7 kWh/m^2 and 515.1 kWh/m^2, respectively.

It is significant to note that IDA ICE software, for calculating supplied energy per meter square has used up the whole base area into account during the calculating's procedure. Furthermore, it has not been considered the fact, there are some spaces did not require heating, and cooling system included (bathrooms, storages, and garage), that gives inaccurate results. Thus, to find out the actual delivered energy per meter squared, the deduction of the space's area that does not require air-conditioning to the total area, when calculated in this manner, it runs out, that type one is actually the best among the others in terms of energy efficiency, which required only 225.5 kWh/m^2. The worst type is type three, which required 606.95 kWh/m^2 as it is shown in *Table II*. In addition, *Fig. 12* shows the total supplied energy for real conditioning area (left), and the required delivered energy per m^2 (right), for residential building typologies.

Table II

The various area and delivered energy in the building models

	Building type-1-	Building type -2-	Building type -3-	Building type-4-	Building type-5-
Model floor area (m^2)	158	80.2	67.8	78.3	200.1
Heated & cooled area (m^2)	158	66.24	62	73.9	155.6
Delivered energy (kWh/m^2)	225.5	357.6	606.95	545.8	400.17
Total delivered energy (kWh)	35629	23687	37631	40335	62256

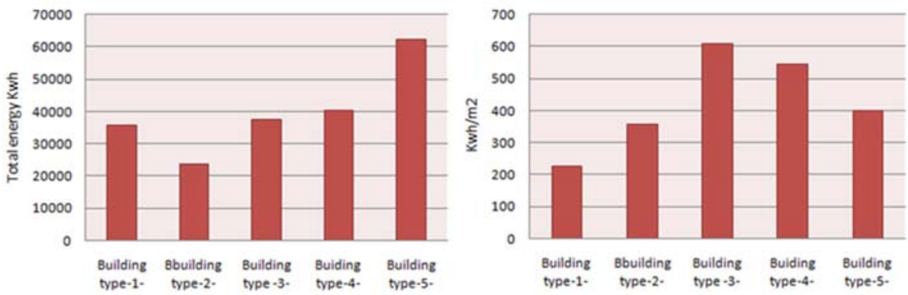

Fig. 12. The total supplied energy (left), the energy required per meter square (right), in the building types

6. Conclusions

The results revealed that the morphologies and compositional attributes of the buildings have a significant influence on the thermal and energy performance. In addition, the size and the volume of the built area also play a big role of energy consumption.

In summation, the building materials and construction techniques also have a substantial part in the energy performance. Thus, the houses that have better thermal mass, they deliver lower energy requirement.

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